

On both points of view, it must be supposed that the luminosity due to α -rays accompanies the dissociation of the active centres and cannot be ascribed to the recombination of the dissociated parts, for there is an undoubted chemical alteration of the material due to continued bombardment.

Whatever point of view is taken, it is clear that for willemite and zinc sulphide the active centres have dimensions comparable with a molecule. This excludes the suggestion put forward at one time that the scintillations of zinc sulphide due to α -particles were a consequence of the mechanical cleavage of small crystals.

I am indebted to Mr. Marsden for the use of the data obtained by him, and for his assistance in calculation of the decay curves.

Measurements of the Absolute Indices of Refraction in Strained Glass.

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1. In June, 1907, the author described* a method by which the double-refraction in strained glass could be measured by observing the deviation of a ray of light passing through a slab of glass under flexure.

If a slab or beam of glass of rectangular cross-section be bent in a vertical plane under a bending moment M , and if a plane wave be transmitted through the glass in a direction perpendicular to the plane of flexure, the light is broken up into two components, one polarised horizontally (*i.e.* perpendicular to the cross-section and along the line of stress) and the other vertically.

It was shown in the paper referred to that the variation in the index of refraction of the glass, due to the stress, produces in the vertically polarised ray an upwards deflection

$$\theta_1 = C_1 M \tau / I \text{ radians,} \quad (1)$$

and in the horizontally polarised ray a deflection

$$\theta_2 = C_2 M \tau / I \text{ radians,} \quad (2)$$

* 'Roy. Soc. Proc.,' A, vol. 79, pp. 440—442.

where τ is the thickness of the glass, I the second moment of area of the cross-section about the "neutral axis," and C_1 and C_2 are the stress-optical coefficients for the vertically and horizontally polarised rays respectively: the stress-optical coefficient for any ray being the increase in the index of refraction for unit tension, or, what is equivalent, the additional retardation introduced per unit thickness per unit tension. In the above, M is reckoned positive when the slab is bent concave downwards.

2. This effect is complicated in practice by the fact that, when a positive bending moment is applied, the upper half of the slab is in tension, and therefore contracts laterally, whereas the lower half is in compression and expands laterally. This transforms the rectangular slab into a prism of very small angle; the additional upwards deflection thus produced is readily calculated and found to be

$$-(\mu-1)\frac{\eta}{E}\frac{M\tau}{I}, \quad (3)$$

μ being the natural refractive index of the glass for the light used, E = Young's modulus, η = Poisson's ratio.

Putting in for I its value $(1/12)\tau h^3$, where h = height of the slab, the deflections actually observed are

$$\theta_1' = 12\frac{M}{h^3}\left\{C_1 - (\mu-1)\frac{\eta}{E}\right\}, \quad \theta_2' = 12\frac{M}{h^3}\left\{C_2 - (\mu-1)\frac{\eta}{E}\right\}. \quad (4)$$

3. In order to apply the correction for change of shape, we immerse the glass in a liquid—cedar oil was actually used—of which the refractive index is known.

This is done by placing a saddle piece ABCD (fig. 1) formed of two parallel pieces of glass AB, CD cemented on to a bridge BC, across the slab, the liquid being held by capillary action in the position shown by the shading.

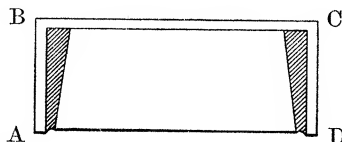


FIG. 1.

When the cross-section of the slab is distorted as shown in fig. 1, the cedar oil wedges formed deflect the rays, the deflection being subtracted from that produced by the change of shape of the glass.

If μ_0 be the refractive index of cedar oil for any given line of the spectrum, then the deflections observed for light of this wave-length are

$$\theta_1'' = 12\frac{M}{h^3}\left\{C_1 - (\mu - \mu_0)\frac{\eta}{E}\right\}, \quad \theta_2'' = 12\frac{M}{h^3}\left\{C_2 - (\mu - \mu_0)\frac{\eta}{E}\right\}. \quad (5)$$

From (4) and (5),

$$\theta_1'' - \theta_1' = \theta_2'' - \theta_2' = 12 \frac{M}{h^3} (\mu_0 - 1) \frac{\eta}{E}. \quad (6)$$

If we denote by Δ the difference $\theta_1'' - \theta_1'$, which is got directly from observation, we have

$$C_1 = \frac{h^3}{12M} \left\{ \theta_1' + \Delta \frac{\mu - 1}{\mu_0 - 1} \right\}, \quad C_2 = \frac{h^3}{12M} \left\{ \theta_2' + \Delta \frac{\mu - 1}{\mu_0 - 1} \right\}, \quad (7), (8)$$

formulae giving the stress-optical coefficients. In the actual experiments Δ was measured for the D-lines, for which $\mu_0 = 1.515$ for cedar oil.

4. The arrangement of the experiment is shown diagrammatically in fig. 2. The light was reflected down a vertical collimator and then diffracted

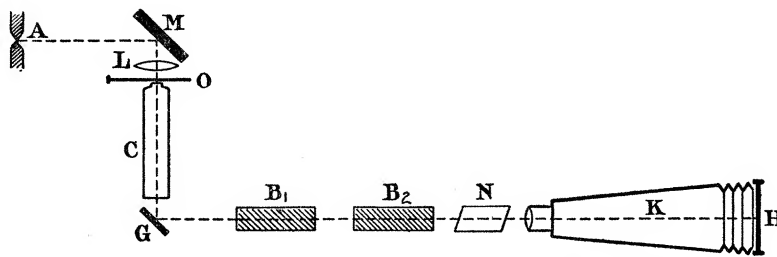


FIG. 2.—A, source of light; M, mirror; L, lens; O, occulting shutter; C, collimator with slit; G, grating; B₁ B₂, slabs of glass; N, nicol; K, camera; H, plate-holder.

horizontally by a reflection grating so as to pass through the glass slabs—two of which were used to obtain a greater effect. The spectrum was then photographed with a camera of about 50 cm. focus. A nicol was interposed in the path of the rays of light between the slabs and the camera. By turning the nicol the horizontally or vertically polarised component could be separately observed; or, if desired, the nicol could be removed and both components observed simultaneously.

An arrangement of weights and levers (not shown in fig. 2) kept the slabs under a constant upward bending moment $-M_0$, as large as was consistent with the safety of the slabs. On moving a lever over, a downward bending moment M was brought into play. M was roughly equal to $2M_0$, so that the addition of M practically reversed the sign of the moment on the slabs without altering its magnitude. In this way a deflection was obtained twice as great as if the bar had been loaded from the unstressed state, and this without increasing the risk of rupture.

5. In taking the observations, half of each exposure was taken with the moment M applied and half without. Two images of each line were thus obtained, and the displacement between the two images on the photographic plate was measured with a micrometer.

To avoid confusion of the two spectra, one was displaced laterally with regard to the other by moving an occulting shutter across the slit at the same time that the moment M was applied. The occulting shutter was so adjusted that the spectra ran side by side, yet partly overlapping, so as to allow the shift of the lines to be measured.

Two plates were taken for each glass, one in horizontally, the other in vertically polarised light. The exposures on each plate searched the whole range of the spectrum which would affect the plate. "Panchromatic" plates, manufactured by Messrs. Wratten and Wainwright, of Croydon, were used. These are fairly uniformly sensitive throughout the visible spectrum.

The scale value connecting shift on the plate with angular deviation was obtained by taking away the grating and replacing it by a double mirror consisting of two mirrors cemented together and making a known small angle i with one another. The two mirrors gave two images of the slit on the plate: the distance between these two images corresponded to a deviation $2i$ of angle.

The light used was an arc lamp burning yellow "flare" carbons. These have their core mainly filled with calcium and give a very bright and steady calcium spectrum, with several of the brighter strontium lines showing.

6. In order to obtain as large an effect as possible, large slabs of length 13 cm., height 1 cm., and thickness 6 cm. were made for me by Messrs. Zeiss, of Jena. As two were employed in each experiment the light traversed 12 cm. of glass.

Two glasses have been examined by this method, bearing the Jena Catalogue numbers O 935 and UV 3199 respectively. The first is a borosilicate, the second a so-called "Uviol" glass, which is fairly transparent to ultra-violet light.

The makers were unable to give the composition of these glasses, and as they are at present required for further work, they have not yet been analysed. On a previous occasion a glass bearing the Jena Catalogue number O 935 was examined by the author. Its analysis gave the following results: SiO_2 , 32.5 per cent.; PbO , 28.2 per cent.; B_2O_3 , 27.7 per cent.; Al_2O_3 , 8.5 per cent.; K_2O , 3.1 per cent.; these, however, can give at best an indication of the composition of the present slabs, which, probably, may differ a good deal from the earlier ones.

7. The stress-optical coefficients C_1 and C_2 have been calculated for a number of spectrum lines, and are given in Tables I and II below. Both are negative, so the tables give $-C_1$ and $-C_2$. These are expressed in a unit of 10^{-10} cm.² per gramme weight.

It would be very desirable to have a short name for this unit, which is constantly occurring in this work. It happens to be of the order of the stress-optical coefficients for ordinary glasses, and is therefore a convenient practical unit. I propose to call it a *brewster*, after the first discoverer of the stress-optical effect.

The displacements measured varied between 0.4 and 5.0 revolutions of the micrometer screw. The latter was graduated to hundredths. The mean of five readings was taken and the average probable error should not have exceeded 0.01 of a revolution. The errors due to irregularities in the plate, photographic irradiation, or stretching of the film, will have raised this somewhat, but the probable error of C_1 or C_2 should not exceed 0.02 of a brewster on the average.

Table I.—Glass O 935.

λ .	$-C_1$.	$-C_2$.	λ .	$-C_1$.	$-C_2$.	λ .	$-C_1$.	$-C_2$.
6500	0.95	4.23	5595	—	4.18	4607	0.86	4.16
6494	0.95	4.24	5590	0.91	4.20	4586	0.85	—
6472	0.90	4.27	5582	0.92	4.19	4579	0.81	4.22
6463	0.97	4.28	5513	0.92	4.16	4527	0.87	4.17
6450	0.95	4.25	5350	0.92	4.17	4456	0.88	—
6439	0.95	4.26	5270	0.91	4.13	4426	0.87	4.14
6169	0.97	4.29	5189	0.86	4.10	4355	0.86	4.13
6103	1.01	4.27	5042	0.86	4.21	4319	0.89	4.09
6065	1.01	4.29	4878	0.88	4.18	4289	0.87	4.14
5896	0.95	4.21	4812	0.89	4.24	4216	0.83	4.10
5890	—	4.21	4722	0.90	—			
5858	0.94	4.23	4685	—	4.22			

Table II.—Glass UV 3199.

λ .	$-C_1$.	$-C_2$.	λ .	$-C_1$.	$-C_2$.	λ .	$-C_1$.	$-C_2$.
6494	0.69	3.87	5270	0.64	3.85	4319	0.58	3.93
6472	—	3.81	5189	0.65	3.88	4308	—	3.93
6463	0.71	—	5042	0.60	3.86	4303	0.61	3.94
6439	0.72	3.82	4878	0.61	3.91	4299	—	3.91
6163	0.70	3.87	4812	0.65	3.90	4290	—	3.88
6123	—	3.85	4722	0.62	3.92	4283	0.59	3.91
6103	0.68	3.86	4678	0.62	3.91	4227	—	3.91
6065	0.66	3.81	4607	0.57	3.91	4216	0.51	3.92
5896	0.66	3.77	4586	0.59	3.93	4166	—	3.95
5890	0.68	3.82	4582	0.59	—	4078	0.55	—
5858	0.72	3.78	4527	0.53	3.92	3969	0.54	—
5590	0.70	3.84	4456	0.61	3.96	3934	0.55	—
5513	0.66	—	4436	0.60	3.97			
5350	0.64	—	4426	0.60	3.93			

[N.B.—In the above table, entries in the column headed C_1 are occasionally missing in the column headed C_2 , and conversely. This is due to the fact that a line which was suitable for measurement on one plate was unsuitable for measurement on another, owing to imperfect or overlapping images.]

The results given in the above tables are exhibited on the diagrams of figs. 3 and 4, the base-line being shifted so as to bring the curves of C_1 and C_2 close to one another for purposes of comparison.

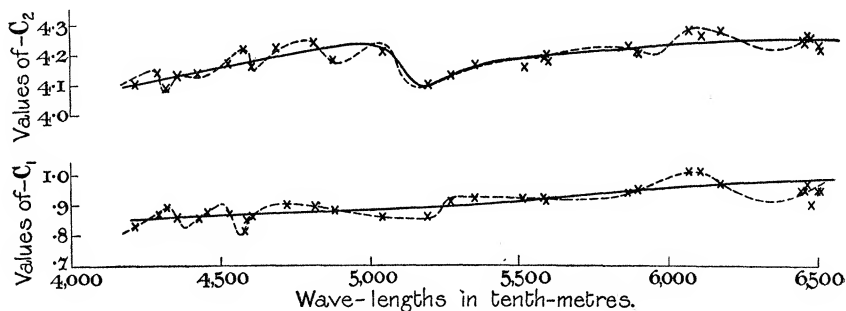


FIG. 3.—Glass O 935.

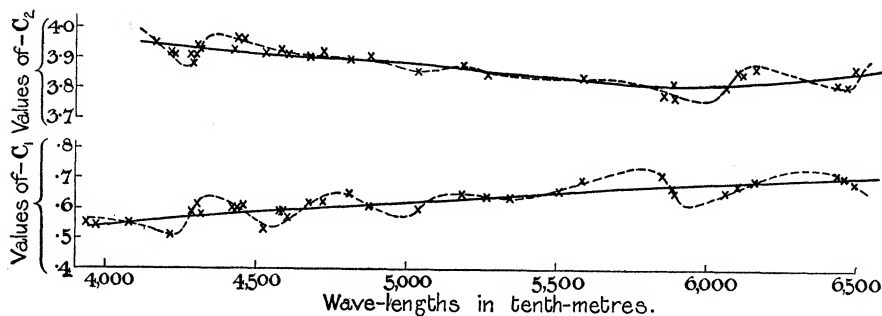


FIG. 4.—Glass UV 3199.

8. With regard to the above results we note the following points.

Since C_1 and C_2 are negative, both rays are accelerated by tension and retarded by pressure. C_2 being numerically greater than C_1 , the ray polarised in the direction of stress is the most strongly affected. The other, however, is affected to a sensible extent.

If we now examine figs. 3 and 4, we see that in O 935 both C_1 and C_2 show a slight numerical *decrease* as we move towards the violet. But in UV 3199, C_1 shows a numerical *decrease* towards the violet, whereas C_2 shows a numerical *increase* in the same direction.

These general variations in C_1 and C_2 appear to be of the same order of magnitude in absolute value; but the *proportional* variation is much greater in C_1 than in C_2 , owing to the smaller value of C_1 itself.

In addition, the above general variation is broken by a number of local irregularities. The most important of these occurs in O 935 between λ 5189 and λ 5042, where there is a large and sudden jump in C_2 of 0.11 of a brewster. This has been tested by careful re-measurement. It confirms a result

obtained some years ago by the author,* when an abrupt oscillation of this sort was discovered in the differential stress-optical coefficient ($C_1 - C_2$) of two other borate glasses. This gave a dip about λ 5050, and rise about λ 4900, and there seems little reason to doubt that we have here the identical irregularity.

In the paper referred to it was conjectured that this might be analogous to the bend in the curve of refraction produced by an absorption band, and possibly due to a free period of some constituent of the glass. At the time it seemed doubtful whether this constituent was B_2O_3 , the bend not having been detected in other borate glasses. Negative evidence, however, is hardly conclusive and the presence of the bend in O 935 rather suggests that it may be characteristic of borosilicates.

The other irregularities are not so marked. Many appear so erratic that at first sight one is tempted to put them down as due to errors of observation and to draw through the observations a smooth curve (shown by the full curve in figs. 3 and 4). There is no doubt that they are very much of the magnitude of the errors of observation, and it is hard to say of any one of them that it is certainly significant. Yet after consideration it may seem that they should not be so easily dismissed. For example, the values of C_2 for O 935 show a little maximum at λ 4579. Taken by itself this means nothing: the line formed by joining successive observations is in this neighbourhood quite irregular and jagged—but, curiously enough, the curve of C_1 shows a little *dip* at precisely the same place, as though some common physical factor had affected the results. Further, in the paper in 'Phil. Trans.' quoted above, $C_1 - C_2$ showed a decided peak in the neighbourhood of λ 4500 for certain borate glasses. All these points, taken together, make one hesitate to condemn this little sinuosity as entirely irrelevant.

Again, there are slight inequalities in C_1 in figs. 3 and 4, near λ 5100, which are insignificant in themselves, but acquire significance from their occurrence at the same place as the characteristic bend previously noticed.

Finally, in the C_1 curve of fig. 4 it is difficult to resist the conclusion that the groups of three observations round 5890, 6100, and 6450 respectively are not disposed as they are by pure chance, but really imply two crests and a trough in the curve, the more so that the three other curves show a rise from 5800 to 6100.

If all these pieces of evidence be taken together and weighed, the conclusion is almost forced upon one that we have here before us a number of bends in the curves, due to various free periods of the constituents of the glasses. The dotted lines of figs. 3 and 4 show a possible course of the curves

* 'Phil. Trans.,' A, vol. 207, pp. 293—301.

but more delicate observations would be necessary before the oscillations, if they exist, can be definitely identified.

9. Incidentally the method provides us with the elastic constants for the glasses used, for η/E can be calculated when Δ is known: and if we take Poisson's ratio to be $1/4$ (which is very nearly Amagat's value for the ratio in glass), we find E . We have

	O 935.	UV 3199.	
η/E	4.28×10^{-10}	2.69×10^{-10}	
E/η	2.34×10^9	3.73×10^9	} grammes weight per sq. cm.
E	585×10^6	932×10^6	

10. In conclusion, I desire to express my best thanks to Prof. F. T. Trouton, F.R.S., and to the Staff of the Physical Laboratory of University College, where the work has been carried out, for their kind assistance and courtesy.

Some Phenomena of Magnetic Disturbances at Kew.

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(Abstract.)

A recent paper* discussed the diurnal inequality of Kew magnetic declination derived from 209 of the most highly disturbed days of the eleven years 1890 to 1900. The present paper discusses the corresponding phenomena for the same days in the other magnetic elements. The most prominent features of disturbed days are the irregular nature of magnetic changes, and the frequency of large oscillations. These more obvious features have hitherto engrossed attention. It is found, however, that the irregular changes on disturbed days are accompanied by large *regular* diurnal changes, which are specially striking in vertical force. In declination and horizontal force the range of the regular diurnal inequality on disturbed days is in the average month of the year about double that on quiet days, but in vertical force the former range is fully four times the latter. Disturbance affects the type as well as the range of the diurnal inequality. The former influence is

* 'Phil. Trans.,' A, vol. 208, p. 205.